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ABSTRACT

The use of intelligent software agents within computer mediated learning environments has become an important focus of research and development in both AI and educational contexts. Some of the roles envisaged and implemented for these electronic entities involve direct interactions with students, participating in the "social" dimension of the classroom that is of such importance in contemporary pedagogical theory. Others contribute to the many background tasks that support the teaching/learning process. Each type of activity raises its own special challenges in relation to the capabilities of the software and to our understandings of teaching and learning. Through discussion of both theoretical perspectives and practical examples, this paper explores a selection of these issues. (Contains 13 references.) (Author)

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Agent Technologies in the Electronic Classroom: Some Pedagogical Issues

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Abstract: The use of intelligent software agents within computer mediated learning environments has become an important focus of research and development in both AI and educational contexts. Some of the roles envisaged and implemented for these electronic entities involve direct interactions with students, participating in the 'social' dimension of the classroom that is of such importance in contemporary pedagogical theory. Others contribute to the many background tasks that support the teaching/learning process. Each type of activity raises its own special challenges in relation to the capabilities of the software and to our understandings of teaching and learning. Through discussion of both theoretical perspectives and practical examples, this paper explores a selection of these issues.

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Introduction

One of the fastest growing applications of AI research is the implementation of computer programs commonly referred to as 'agents'. Among the features distinguishing this type of software from more traditional programs are a high degree of autonomy in decision making and action, the ability to 'learn' from experience and to adapt their behaviour accordingly, and often a highly personified interface. Many are specifically designed to process complex information, make decisions and initiate actions in 'mission critical' areas of human endeavour including health, scientific research, business, defence and increasingly in education. While in some cases we are aware of our interactions with these electronic entities, in many contexts their activity takes place 'behind the scenes', at a level not apparent to the user. Agent roles currently implemented in educational projects around the world include record keepers, information seekers, testers, facilitators of collaboration, tutors or instructors, fellow learners, and tutees.

While the usefulness of this type of software in many contexts is already well proven, a number of issues in relation to its uses in education are not yet fully resolved. The substitution of computer programs possessed of varying degrees of artificial intelligence and 'personality' for various aspects of human presence in the computer based classroom, raises some quite fundamental questions concerning the processes through which knowledge is socially constructed, and the qualities which are necessary to ensure successful participation in those processes. To what extent can socially interactive roles such as tutor and fellow learner be effectively and appropriately fulfilled by a computer program, however 'intelligent'? Where agents undertake less interactive tasks such as record keeping and testing, other issues arise including that of privacy and of students' control over their own learning.

Agents in the electronic classroom

Typical of the broad vision held by many researchers and educators for the implementation of agent technology in the online classroom is that promulgated by Johnson, who writes:

> "Pedagogical agents are autonomous agents that support human learning, by interacting with students in the context of interactive learning environments. They extend and improve upon previous work on intelligent tutoring systems in a number of ways. They adapt their behaviour to the dynamic state of the learning environment, taking advantage of learning opportunities as

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they arise. They can support collaborative learning as well as individualized learning, because multiple students and agents can interact in a shared environment. Given a suitably rich user interface, pedagogical agents are capable of a wide spectrum of instructionally effective interactions with students, including multimodal dialog. Animated pedagogical agents can promote student motivation and engagement, and engender affective as well as cognitive responses" (Johnson 1998, p. 13).

Arguably the most obvious choice of interactive role for an agent would be that of teacher. While one might reasonably fear a resurgence of the heavily instructionist model of 'the computer as tutor' prevalent in the early days of educational computing, there are indications that developers are attempting to base their agent-based manifestations on aspects of pedagogical theory more acceptable to current thinking.

As Solomos and Avouris (1999) write, for instance:

"The user mental model of the system should be based on the metaphor of the 'invited professor' rather than the 'knowing everything own tutor'. ... Our first findings confirm the observation that today's users, accustomed to hypertext -like interaction, are more likely to accept this collaborative teaching metaphor, according to which their tutoring system is viewed as an intelligent hypertext browser, offering links to other tutoring systems with the right content and at the right time" (Solomos & Avouris 1999, p. 259).

The image of the teacher as a facilitator of learning rather than as the 'sage on the stage' is also reflected in such statements as: "Each student working on the project will have an agent, operating in the background, watching progress, measuring it against the plan, and taking remedial action when necessary" (Whatley et al 1999, p. 362).

The substitution of agents for one or more of a student's classmates or fellow learners is an interesting concept being explored by a number of developers. Successful implication of this idea would add considerable appeal to online learning environments. Currently, while electronic interactions between students can be encouraged and facilitated up to a point, the quality and timing are far less subject to the control of the 'teacher' than is the case in a face to face situation. The presence of 'classmate agents' would not only enhance the general social ambience of the online classroom, but could enable more constructive interactivity to take place at pedagogically appropriate times.

Since the 1980s Chan (Chan 1996, 1998) and colleagues have been working on a range of models of socially interactive agents for learning environments, perhaps the best known being the 'learning companion' – a software entity having limited knowledge of the domain in question, conceptualised as a fellow learner with whom the student may collaborate and even disagree. As in real life, some of these learning companions may be better informed than the student in the relevant domain of knowledge, while others may know less. Perhaps not surprisingly, in learning environments for younger students, animals are a popular choice of persona for such agents, as in this example of a networked learning environment for Taiwanese high school students, as described by Chan:

"The Dalmation is having the same performance as the student. ... Another animal companion is Dragon, like one of those animal companions in Mulan, a Disney cartoon of this summer. This dragon will "learn" (mainly rote learning) from the student and also from other students on the Net and so may know more than the student. At certain point it'll stop learning and come back to teach the student. In a way, Dragon is protecting the student."
(Chan 1998)

An interesting development of this concept is suggested by Sheremetov and Nunez (1999, p. 310), who describe the function of a 'monitor agent' as being to modify the role, behaviour or expertise of learning companions. A learning companion's personality could, for examples, be changed from that of strong group leader to a weaker companion or even a passive observer, depending on the monitor agent's interpretation of the degree of guidance required by the learner.

A third socially interactive role that may be enacted by an agent is that of 'tutee'. We are all familiar with the common wisdom that we learn best through teaching others. This principle was invoked in the early days of educational computing through Logo, where 'teaching the turtle' was the chosen metaphor for the activity of programming. More recently, a number of researchers have explored the translation of this concept into electronic learning contexts where agents exist to be 'taught' by the student user, as in the example from Chan quoted above. A further example is described by Ju (1998) who writes of a computer based peer tutoring system employing two categories of agent – an 'expert', and a 'learner':

> "... students become active learners who are guided to learn by teaching a computer. After the students watch how the computer expert solves a set of linear equations [the program] helps the human student act as a teacher in order to learn more about the subject matter. At this time, the computer plays the role of a student ..."
> (Ju 1998, p. 559)

In addition to these highly visible and interactive 'social' roles, there is considerable scope for agents to undertake a range of support activities including monitoring the activities and responses of students, administering tests, recording results and seeking information on behalf of students or teachers. The latter task is, of course, familiar to us in relation to the operation of standard Internet search engines.

Issues for consideration

Each of these implementations of agent technologies raises issues that demand consideration. While some are basically pedagogical, others straddle the boundaries between pedagogy and other areas, such as ethics. While some relate to whether or not the achievement of certain ends is a practical possibility, others go further and question whether what is possible is necessarily desirable.

A key element in the implementation of socially interactive agents is a high degree of personification or 'character'. It is well accepted that an element of personification of program interfaces is inevitable. As Shirk puts it:

> "Although there is some dispute among software critics concerning the advisability of having 'personalities' in computer programs, their presence seems unavoidable. Any time there is communication between a computer and a human, the information presented by the computer has a certain style, diction, and tone of voice which impact upon the human's attitude and response toward the software" (Shirk 1988, p. 320).

Deliberate personification is, however, more problematic. As Masterton notes: "A common problem with AI programs that interact with humans is that they must present themselves in a way that reflects their ability. Where there is a conflict between the ability of the system and the users' perception of that ability a breakdown occurs and users may either fail to exploit its full potential or become frustrated with its shortcomings" (Masterton 1998, p. 215). He suggests the implementation of a style of pedagogical agent with a degree of anthropomorphism intended to convey qualities such as friendliness and usefulness, without the implication of possession of full human capabilities. He describes the development and role of such an entity, a VTA (Virtual Teaching Assistant), which is able to introduce topics and answer simple questions, the more complex types of exposition and interaction being left to the human teacher. In terms of a traditional scenario at university level, the VTA functions somewhat like a tutor or demonstrator as distinct from a lecturer. "In this way faculty is left free of the guiding and assisting issues of the course and is able to concentrate on more complex questions and higher level issues generated during the course" (Masterton 1998, p. 211). The 'learning companions' of Chan mentioned above can be seen as further instances of this principle. Our expectations in regard the cognitive skills of animals may well be more appropriate to the capabilities of software agents than are our experiences of human-to-human interactions.

An agent's capacity to demonstrate some equivalent to the emotional responses of a human being, and to appropriately recognise and respond to the emotions of users is becoming recognised as an important element both in personification generally and in educational contexts in particular. As Frasson writes, "Emotions play an important role in the learning process and new strategies have to take into account this human factor for improving knowledge acquisition. Intelligent agents can hep in this process, adding emotional behavior to believability of their actions" (Frasson 2000, p. 60).

Apart from the possibility that less fully personified agents might be more educationally effective, there are clear ethical issues attached to the presentation of these programs in a form which students are unable to distinguish from that of a human participant in the learning experience.

Another important characteristic of agent software is its capacity for autonomous or self-directed decision making and action in the pursuit of its goals. This raises the question of the extent to which a pedagogical agent should be furnished with pre-existing goals which could lead it to undertake actions without instruction from the learner, and even contrary to what the learner might perceive as his or her interests and wishes. Loeffler (1996) notes that the unpredictability resulting from significant autonomy might well result in

agents who are less 'helpful' to us than we might hope or indeed expect. As Minsky puts it, "There's the old paradox of having a very smart slave. If you keep the slave from learning too much, you are limiting its usefulness. But, if you help it to become smarter than you are, then you may not be able to trust it not to make better plans for itself than it does for you" (Minsky, 1994, p. 25). It is easy to slip from such considerations into the need for a contemporary version of Asimov's laws of robotics as conceived in fictional terms more than 30 years ago.

In educational contexts there is potential for some degree of conflict between the usefulness of an agent possessing a high degree of autonomy, and contemporary understandings of the importance of individuals being able to exercise control over various aspects of their own learning. It could be argued that current trends in educational thinking which favour giving more control and autonomy to the learner would appear to be more in line with the thinking of researchers such as Schneiderman (1983) who favour 'direct manipulation' over the development of interactive agents with a significant degree of independence of action. There is certainly a case for suggesting that pedagogical agents be configured so as to be particularly sensitive to individual user models, more responsive to instruction from the user/student, and that their characteristics and capabilities should be more transparently presented.

A high degree of transparency in relation to the functioning, indeed to the existence of agents within the electronic classroom is also important in relation to maintaining a level of trust which many educators believe to be an important component of any learning environment, whether computer based or face to face.

A further concern in regard to the autonomy of pedagogical agents relates to the issue of intervention in the learning process. It is well accepted that a high degree of unsought assistance whether from a human teacher or an excessively diligent and proactive agent can be quite detrimental, in particular to the metacognitive aspects of learning. The fact that this is also an issue for teachers and learners in face to face educational contexts underlines its complexity, and degree to which it is unlikely to handled with the requisite sensitivity through prior programming of an agent.

An interesting aspect of most agent based educational systems is their use of a multiplicity of agents, many of them capable of a complex range of interactions with the student, with one another, and increasingly with agents associated with other programs. These interactions range in nature from collaboration to competition, and their purposes are derived from theoretical analyses of the various component tasks and activities that make up the human activity of 'teaching'. An example is the Multiple Agent Tutoring System (MATS) described by Solomos and Avouris:

> " MATS is a prototype that models a "one student-many teachers" learning situation. Each MATS agent represents a tutor, capable of teaching a distinct subject. All MATS tutors are also capable of collaborating with each other for solving learning difficulties that their students may have" (Solomos & Avouris 1999, p. 243).

While on the one hand, the variety of functions of agents within a multi-agent environment is an attempt to realise the type of rich user interface which Johnson suggests is necessary if the pedagogical interactions within electronic learning environments are to approximate to any degree to the face to face educational experience, some educators have concerns in regard to the assumptions underlying these practices. They argue that such developments are underpinned by a reductionist rather than a holistic understanding of the processes and relationships involved in teaching and learning. In separating out the different components of pedagogical interactions, are we enabling each part to be realised more effectively, or are we failing to acknowledge that the global act of human teaching may in fact be more than the sum of its component parts?

Central to the work of many theorists and researchers is the belief that it is possible for agents to participate effectively in the social aspects of knowledge construction. Sheremetov and Nunez, for example, whose works derives overtly from the theoretical frameworks of Piaget and Vygotsky, argue that:

> "The design of learning environments, virtual or not, aims to promote productive interactions. In this type of learning a student changes from being a passive information receiver to an active collaborator, interacting with the tutors and colleagues in the learning process. Learning does not only result from acquiring knowledge, solving problems or using tools, but also from interacting about these on-going activities with persons and agents"(Sheremetov and Nunez 1999, p.305 – 306).

But however personified and autonomous the software agent, can it really be said to participate fully in the social construction of knowledge? It has been argued quite extensively that even the most heavily personified of computer programs suffer from an intrinsic lack of ability to participate in the metacognitive aspects of learning. Pufall (1988), for instance, expresses a strong belief that a computer program is unable at any

level commensurate with human capacities to modify its own knowledge structures or cognitive processes, and so cannot be regarded as a co-constructor of knowledge in a meaningful sense. While this might well have been the case in relation to earlier computer based learning environments, can we continue to make the same claims with confidence today or in the future? The capacity of software to 'learn' and adapt to experience through the incorporation of new information, the appropriate modification of its representation of the context in which it functions (its 'world') and of its inference mechanisms, is undoubtedly increasing. If our test of full participation depends on an understanding that the agent has 'learnt' in precisely the same way that the human has learnt, then we will have difficulty accepting the electronic entity as genuine co-constructor of knowledge. If, however, we make our claim on the grounds that it appears to the human learner that the agent has participated in the learning that has taken place, then perhaps we can at least tentatively admit such a piece of software to membership of the social milieu that has mediated the educational experience.

Conclusion

The widespread implementation of agent technologies within the electronic classroom is bound to raise a large number of issues of which those listed above are a sample. While it is critical that pedagogical concerns rather than simple technical capabilities are the driving force behind the development of these new learning environments, it is also important to look beyond the extent to which agents can simply replicate existing classroom conditions. Where agent based educational systems can be identified as differing from the traditional classroom, careful research and critical evaluation is required if we are to distinguish between those which simply undermine valued aspects of the educational enterprise as we understand it, and those which have the potential to create fruitful new possibilities in regard to how we teach and how we learn.

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